Laser Engineered Net Shaping (LENS)

An NCMS CTMA Collaborative Program

Mike Gnam -NCMS
Rich Plourde -Optomec
Tom McDonald -Laser Fare

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Background

- Laser Engineered Net Shaping Project (LENS)
- NCMS Collaborative Project
- Conducted under the CTMA Program at NCMS
- Mission to improve the repair and overhaul capabilities of DoD maintenance depots

LENS Program

- The Problem
  - Develop new methods and applications of repair and overhaul technologies to extend the life of aging aircraft, ship, vehicles, and weapon systems
  - Conventional repair techniques such as MIG or TIG Welding induce excessive heat and a large HEAT AFFECTED ZONE (HAZ) destroying usefulness of the part

LENS Program

- The Problem (cont.)
  - High cost of scrapping or maintaining critical parts, especially, when drawings do not exist.
  - Parts deemed non-repairable or scrapped during the repair process

LENS Program

- The Solution
  - Form a collaborative project under the CTMA program between DOD and commercial industrial partners to apply LENS technologies to specific participant applications.
  - Develop the equipment and pilot the applications of this LENS technology to new shapes and new materials than previous state of the art.

CTMA LENS
Phase I Project Participants

NCMS
Project Management

Anniston Army Depot
End User

Teamwork

Partnership

laser fare, inc.
An Infinite Group Company
Mfg Service Provider

OPTOMEC
Eqpt Mfg/Tech Provider

Ford
End User

Pratt & Whitney
A United Technologies Company
End User

NCMS
Collaboration that works.

LENS PROGRAM

- Tasks
  - Build two 1100W LENS units for applications at depots and industrial partners
  - Address process development issues (mat’l condition, geometries,tool paths, build rates, accuracy, surface finishes, etc
  - Investigate embedding sensors
  - Investigate alternate material applications (e.g. aluminum)
  - Industrial tooling repair applications
  - Benefit analysis

LENS PROGRAM

- Current program is 18 months ending in June 2001
- Participants looking to form LENS II
  - Possible alternate materials
  - Possible portability
- Depot Tour underway looking at applications and creating awareness

LENS PROGRAM

- Further Detailed Description
  - LENS Technology
  - LENS Applications
  - Specific Real World Examples
  - Cost Benefits to DoD

LENS Technology & Applications

LENS Technology Overview

Rich Plourde

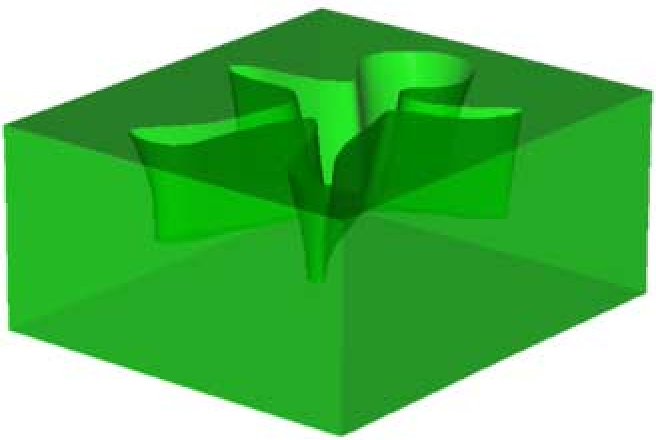
CTMA LENS Project Statement of Work

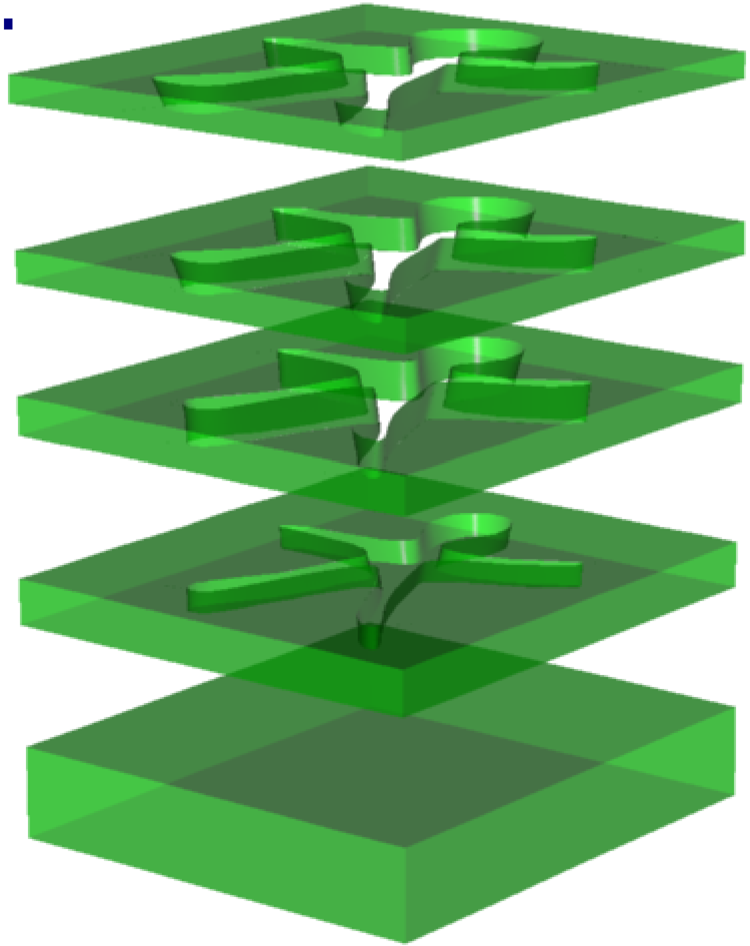
Tom McDonald

OPTOMEC

Traditional Rapid Prototyping Techniques

3D parts fabricated from 2D layers.





- STL File input
- Hatch & Contour filling

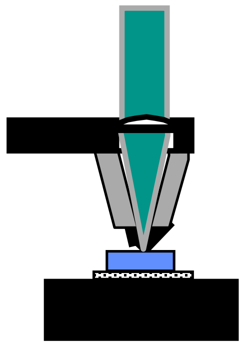
ncms Collaboration that works.

LENS Process for part fabrication tool path

Wind Tunnel Test Part

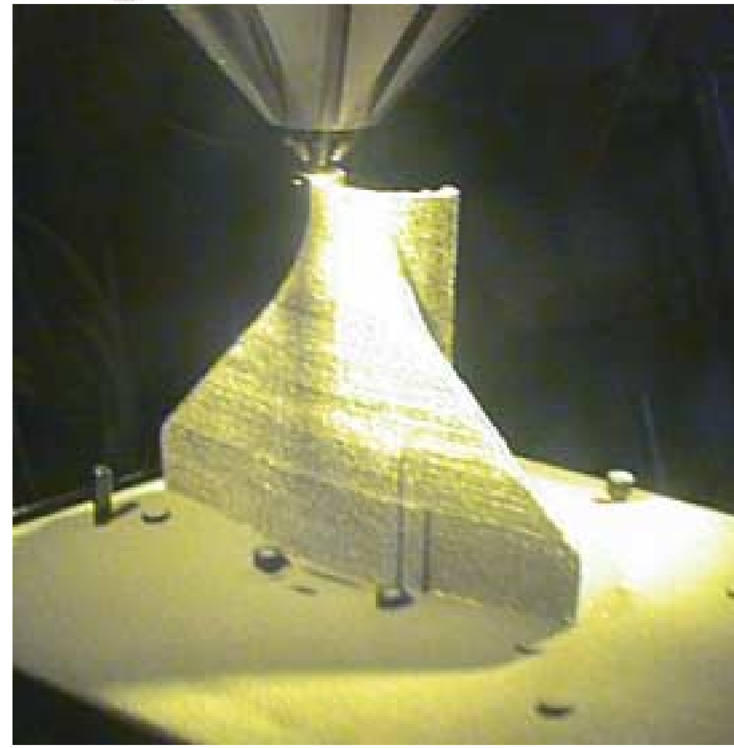
Design | ***Process*** | ***Part***

CAD to STL file
Process Set Up



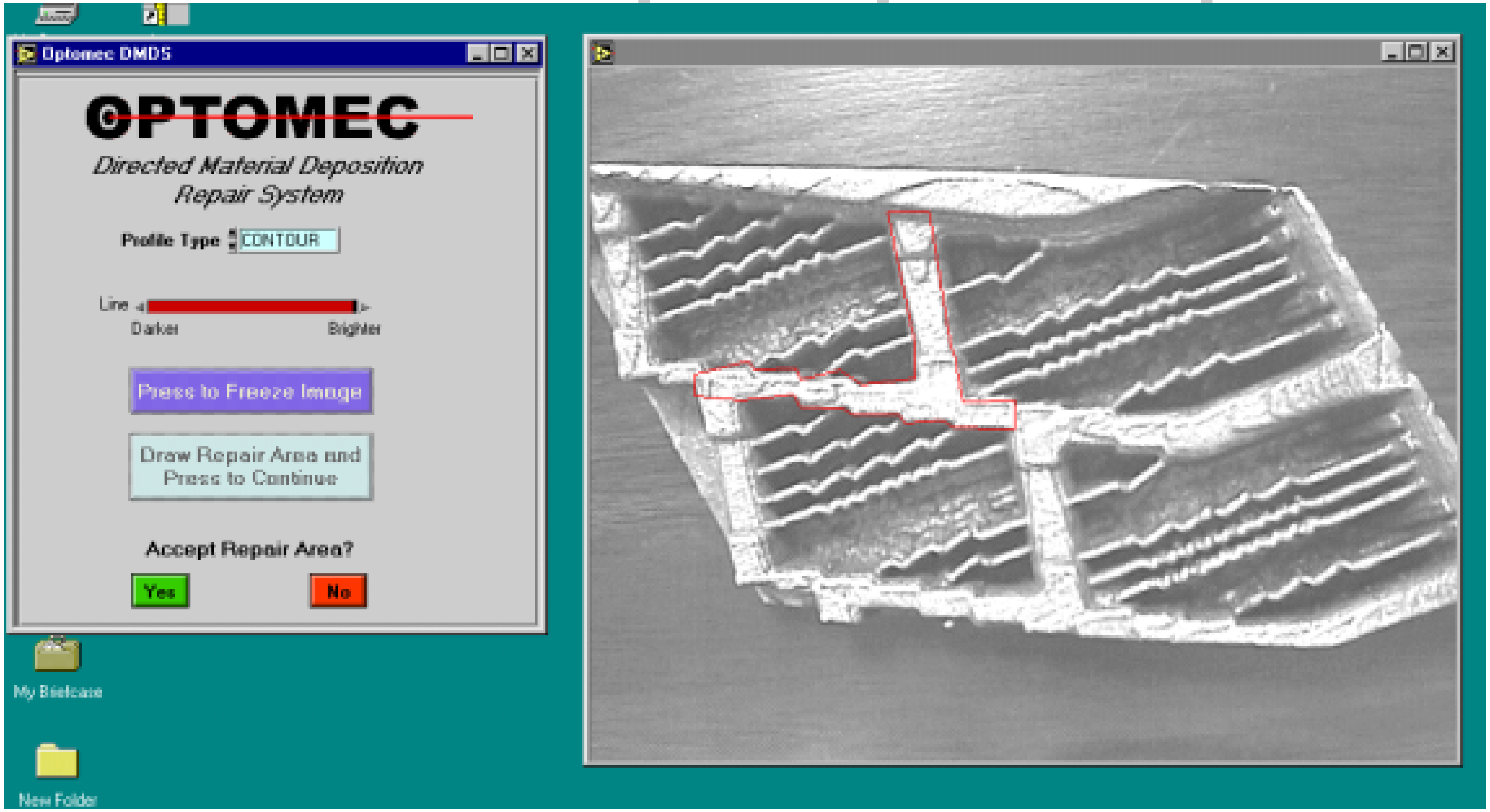
Fully Dense Part
Near Net Shape

4 Nozzle Powder Delivery
Powder melted via YAG Laser
Layer by layer part build/repair
Up to 5 Axes range of motion powder delivery



Optomec LENS offers a multi-functional enabling technology platform, providing solutions for a wide range of applications.

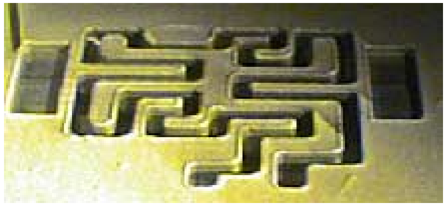
LENS Process for part repair tool path



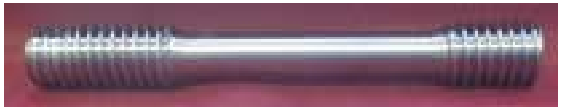
- The repair area is sketched using the mouse.
- Tool path is created.
- Operator “dials in” process parameters in computer controlled system.

LENS Process Advantages

- Additive 3D fabrication of embedded structures.



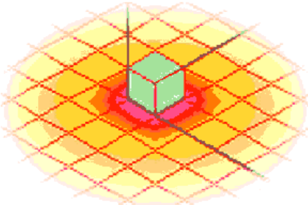
- Computer controlled gradient deposition of multiple materials within a single part.



- Exceptional material properties.

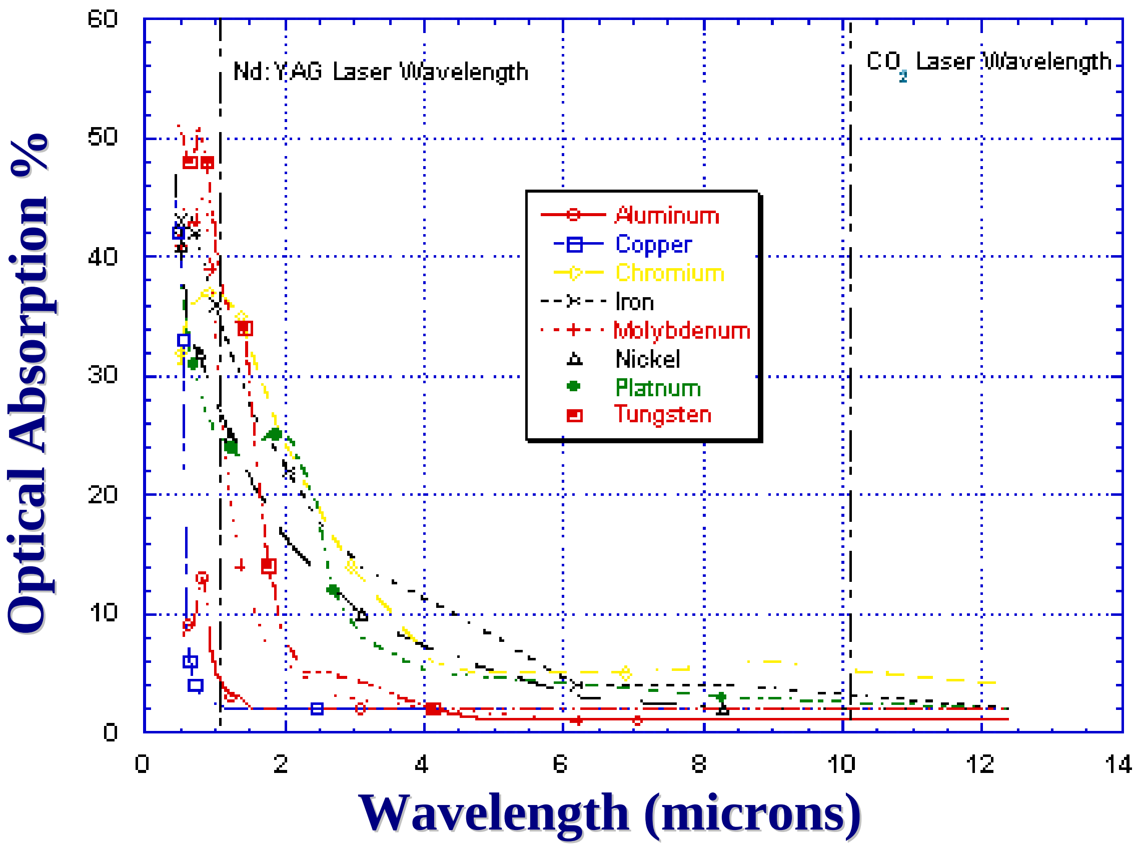
Material Type	Ultimate Strength (ksi)	Yield Strength (ksi)	Elongation (% in one inch)
Optomec DMDS 316 Stainless Steel	115	72	50
316 SS Wrought Stock	*85*	*35*	*50*
Optomec DMDS Inconel 625	135	84	38
Inconel 625 Wrought Stock	*121*	*58*	*30*
Optomec DMDS Ti-6Al-4V	170	155	11
Ti-6Al-4V Wrought Stock	*130*	*120*	*10*

- Small Heat Affected Zone (HAZ).



Nd: YAG Laser Absorption Irradiance

Optical Absorption vs Wavelength



- Since it is undesirable to vaporize the material as it is deposited, it is the optical absorption of materials that is critical to the LENS laser free form fabrication process.
- With the exception of copper, all of the elemental metals shown in this graph have significantly higher absorption at the Nd:YAG laser wavelength as compared to the CO_2 laser wavelength.

ADVANTAGE: Small Heat Affected Zone (HAZ)

BENEFIT: No part distortion or micro cracking

Anniston Army Depot

OPTOMEC

Estimated Annual Cost Savings

Inconel 625 - 15 Min

SS316 - 5 Min

ITEM #1
Third (3rd) Stage Turbine Rotor

ITEM #2
Fourth (4th) Stage Turbine Rotor

ITEM #3
Second (2nd) Stage Nozzle

ITEM #4
Compressor Stator 1st L.P.

LASER ENGINEERED NET SHAPING (LENS) - ESTIMATED PER YEAR COST SAVINGS

ITEM	PART	MATERIAL	PART NUMBER	NEW PART COST	ESTIMATED REPAIR COST	SAVINGS PER PART	PARTS REPAIRED PER YEAR	SAVINGS PER YEAR
1	Third (3rd) Stage Turbine Rotor	M3610C/Inconel 713LC	12271565	$ 8,297	$ 2,000	$ 6,297	230	$ 1,448,416
2	Fourth (4th) Stage Turbine Rotor	M3610C/Inconel 713LC	12281566	$ 5,485	$ 2,000	$ 3,485	230	$ 801,529
3	Second (2nd) Stage Nozzle	M3602/Inconel 713C	12286886	$ 6,032	$ 2,250	$ 3,782	600	$ 2,269,140
4	Compressor Stators (H.P. and L.P.)							
	1st L.P.	AMS 5510/321 Stainless	12302430	$ 910	$ 300	$ 610	175	$ 106,759
	2nd L.P.	AMS 5510/321 Stainless	12286149	$ 1,170	$ 300	$ 870	175	$ 152,264
	3rd L.P.	AMS 5510/321 Stainless	12302480	$ 610	$ 300	$ 310	175	$ 54,304
	4th L.P.	AMS 5510/321 Stainless	12286161	$ 611	$ 300	$ 311	175	$ 54,495
	5th L.P.	AMS 5510/321 Stainless	12302429	$ 701	$ 300	$ 401	175	$ 70,091
	1st H.P.	AMS 5504/410 Stainless	12286257	$ 604	$ 300	$ 304	175	$ 53,155
	2nd H.P.	AMS 5504/410 Stainless	12286261	$ 1,188	$ 300	$ 888	175	$ 155,377
	3rd H.P.	AMS 5504/410 Stainless	12286266	$ 575	$ 300	$ 275	175	$ 48,038
	4th H.P.	AMS 5504/410 Stainless	12286568	$ 1,893	$ 300	$ 1,593	175	$ 278,782
5	Fourth (4th) Stage Seal Runner	AMS 5662/Inconel 718	12286490	$ 319	$ 200	$ 119	600	$ 71,268
				$ 28,395	**$ 9,150**	**$ 19,245**		**$ 5,563,617**

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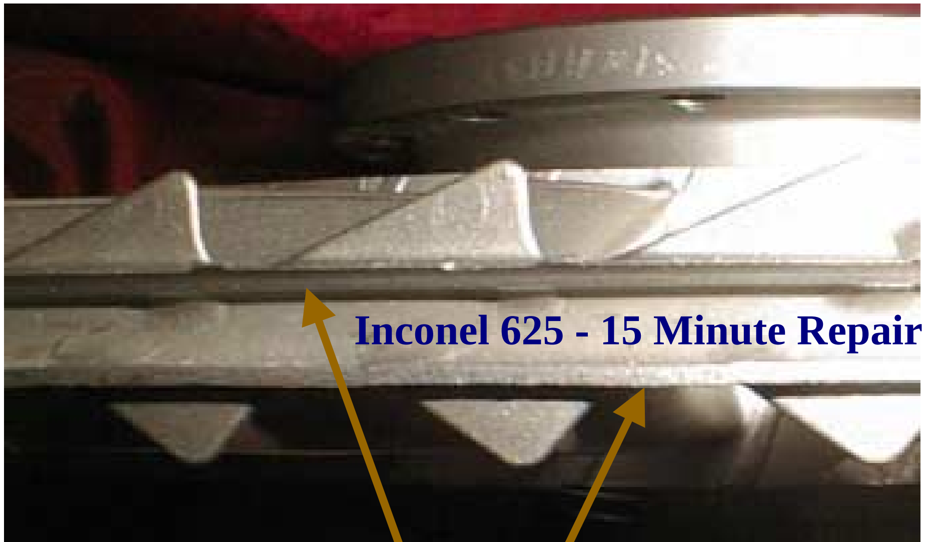
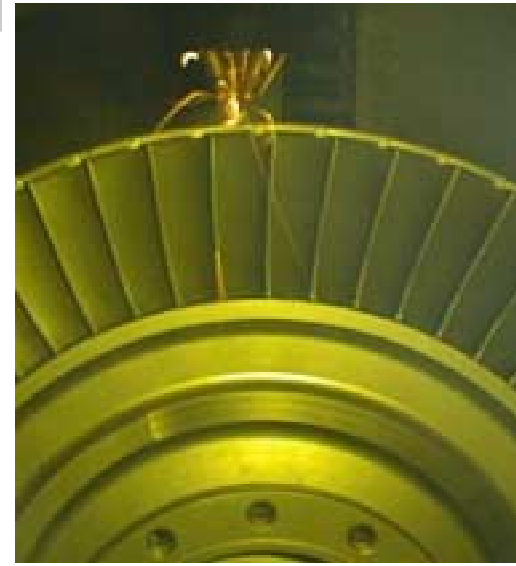
3rd Stage Turbine Rotor Repair





Area of Repair

.040”

“Depot and contractor level repairs utilizing welding & bonding techniques have yielded limited success due to base metal cracking.”

Brian Rich - ANAD

CTMA LENS Model 842

PHASE I FEATURES

- 1100 Watts of cw Nd:YAG Laser Power
- Fiber Optic Beam Delivery
- 18"x18"x42"(z axis) build envelope
- 3 Axis of Laser & Powder delivery
- 4th & 5th Axis Tilt / Rotary Fixturing Stage
- 2 Powder Feed Units for gradient depostion
- Hermetically sealed Class I Laser Enclosure
- Controlled Atmosphere Environment with Oxygen Sensor for process control
- Filtering System for Particulate Control
- CCD Vision System
- Closed Loop Computer Controlled System
- Power requirements = 208V-3 Phase-100A
- Industrial Hardened Windows NT workstations and electronics with front panel for easy access and monitoring.

CTMA LENS Applications

laser fare, inc.
An Infinite Group Company

LENS Project
Statement of Work

Tom McDonald

CTMA/LENS STATEMENT OF WORK

PROCESS DEVELOPMENT

- **Part/repair preparation**
  - Material condition, repair geometry & CAD file, tool path
- **Part/repair build**
  - Build rates, material properties, geometry accuracy
- **Part/repair finishing**
  - Auto/mechanical, manual, post-treatment (e.g. heat treat)
- **General issues**
  - Customer process qualification requirements
  - Regulatory process qualification requirements
  - Feasibility studies (cost vs.accuracy, cost vs. properties)

CTMA/LENS STATEMENT OF WORK

APPLICATIONS

- **Prototypes**
  - Functional, smart
- **Repairs**
  - Failures in field , fabrication scrap and rework
- **Small lot production**
  - Spare parts, new / development parts
- **Legacy part production**
  - From CAD, reverse engineering
- **Improvement of properties in existing alloys and composites**
- **Development of new alloys and composites**

CTMA/LENS STATEMENT OF WORK

- APPLICATIONS
  - **Lowest hanging fruit (i. e. best ROI for time spent)**
    - Parts scrapped and replaced with new parts
      - large HAZ (distortion, destroyed substrate microstructure)
      - excessive remachining after deposition
    - Ideal scale and geometry
      - one foot cube, thin walls, low aspect ratios
    - Ideal materials
      - Ti6V4Al, Inco 625, Inco718, 316 SS, H13
      - gradients (CTE mismatch, etc.)
    - Chronic repairs
      - more robust coatings
    - Faster

Next Steps

- **Identify applications for LENS Phase I and potential LENS Phase II Projects.**
  - **Salvaging non-repairable parts**
- **Possible Phase II Projects**
  - **Optimize aluminum fabrication and repair**
  - **Configure LENS system for portable applications**
  - **Embedded Sensors**
  - **Establish process parameters for various materials**
  - **Gradient material optimization**
  - **Application specific nozzle design for line of sight deposition**

THANK YOU

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LENS PROGRAM

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